Soil moisture biases and their correction in CanSIPS operational forecasts

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The Canadian Seasonal to Interannual Prediction System (CanSIPS)

- Developed at CCCma
- Operational at CMC since Dec 2011
- 2 models CanCM3/4, 10 ensemble members each
- Forecasts initialized at the start of every month
- Hindcast verification period = 1981-2010
- Forecasts contribute to **NMME** and WMO/APCC/IRI ensembles
- Forecast range = 12 months

Reference: Merryfield et al., *MWR*, 2013

CanSIPS contribution to NMME

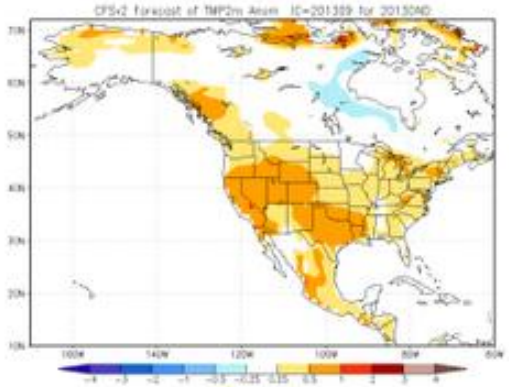
Season 1 tmp2m forecast

IC=201309 for 20130ND

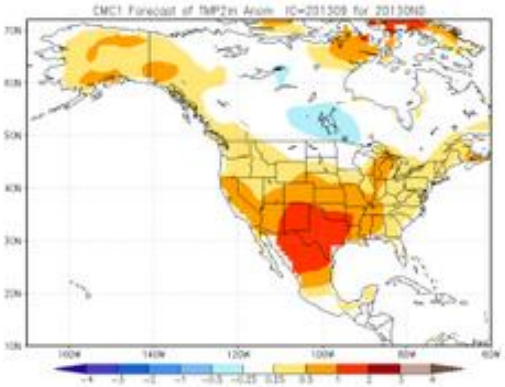
CanCM3

CanCM4

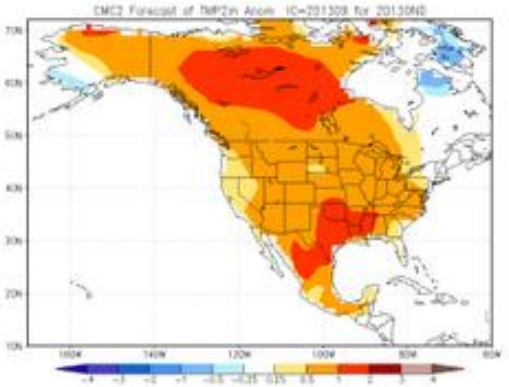
CFSv2



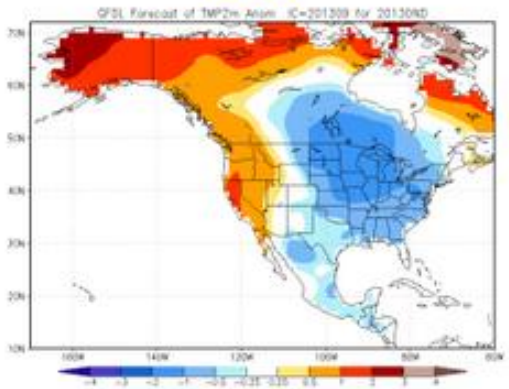
CMC1



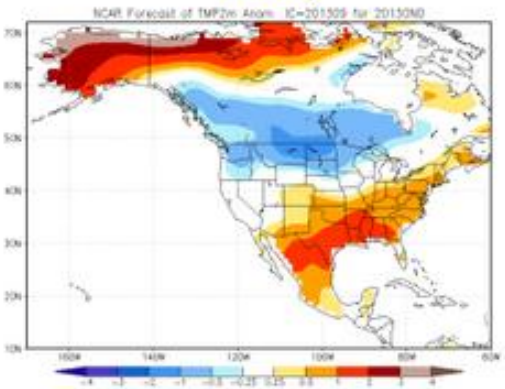
CMC2



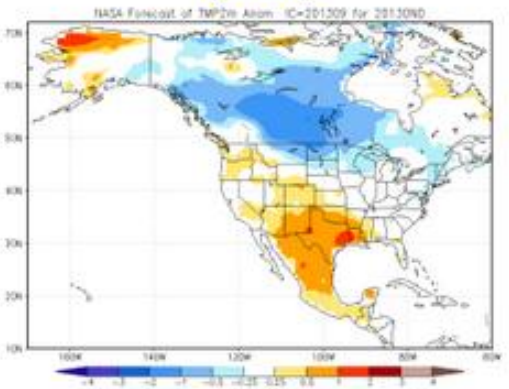
GFDL



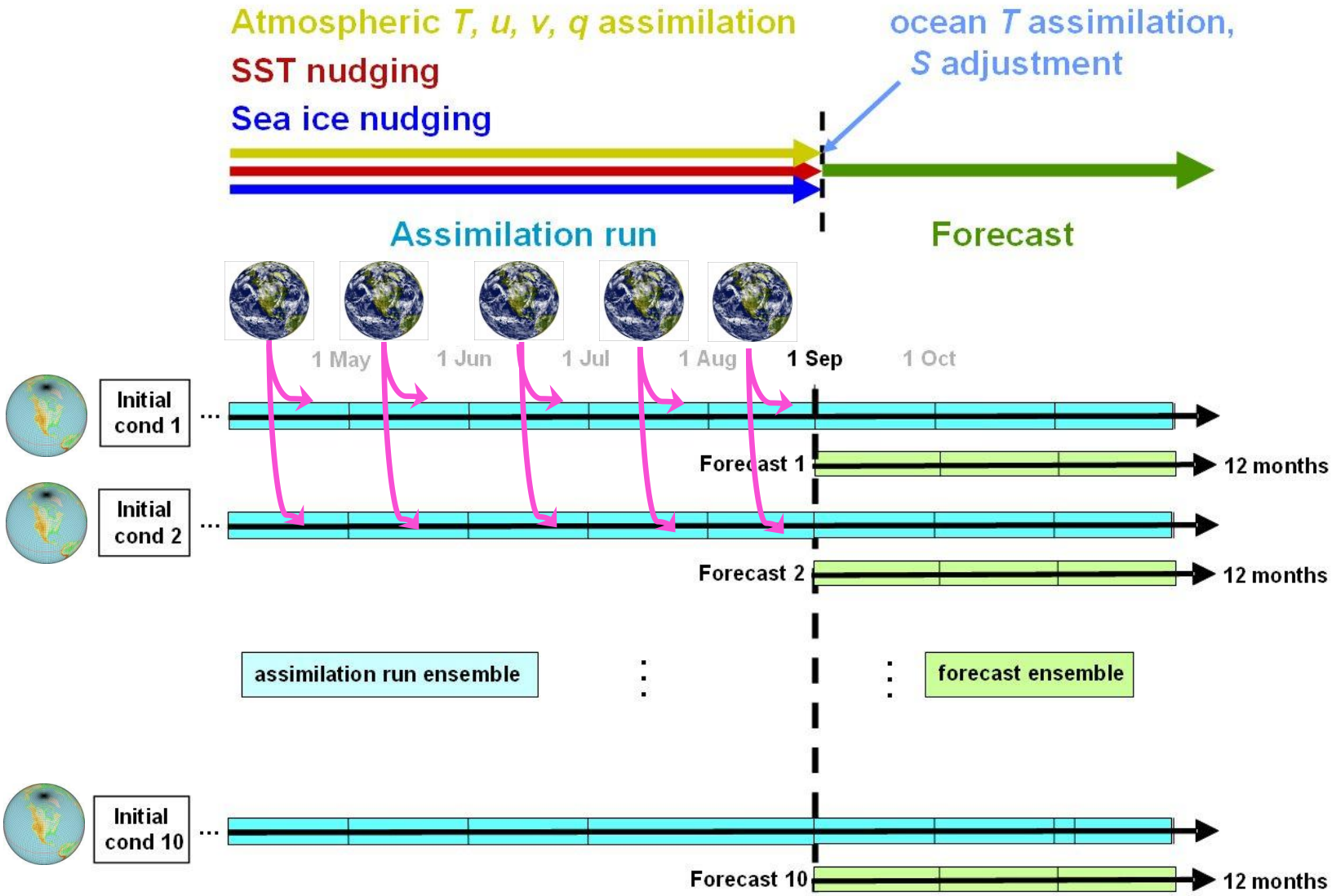
NCAR



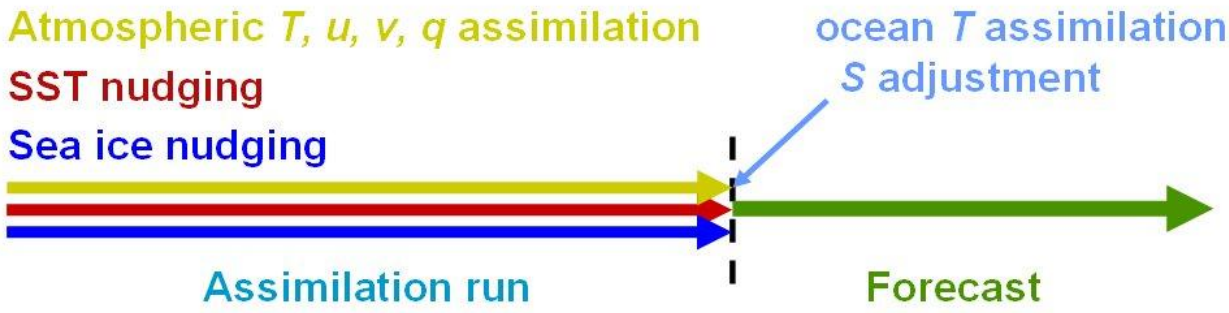
NASA



CanSIPS initialization

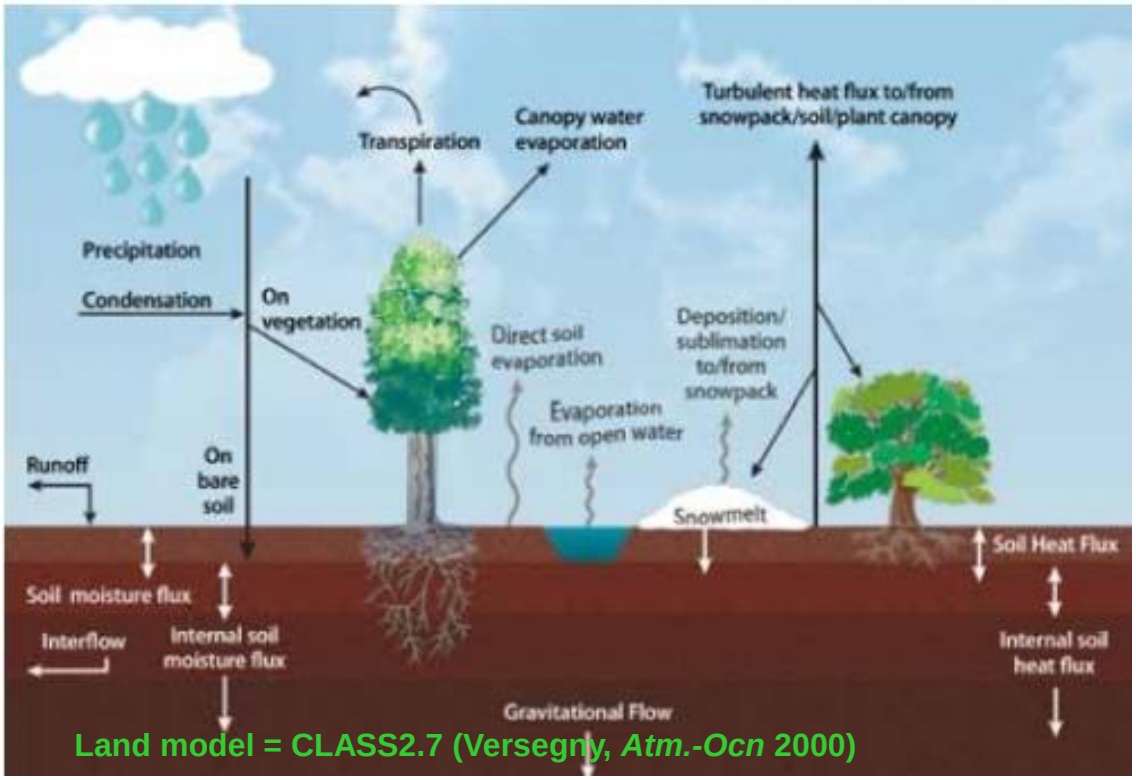


CanSIPS initialization



"Burst initialization"

CanSIPS Land initialization



www.eoearth.org/view/article/152990

Direct* atmospheric initialization through 4D assimilation of 6-hourly *T, q, u, v* using *incremental analysis update (~nudging)

***Indirect* land initialization through response to model atmosphere**

Land surface variables, e.g. soil moisture and snow, are not directly constrained; their states are determined by model response to previously assimilated "weather systems" from 3D atmospheric global analyses.

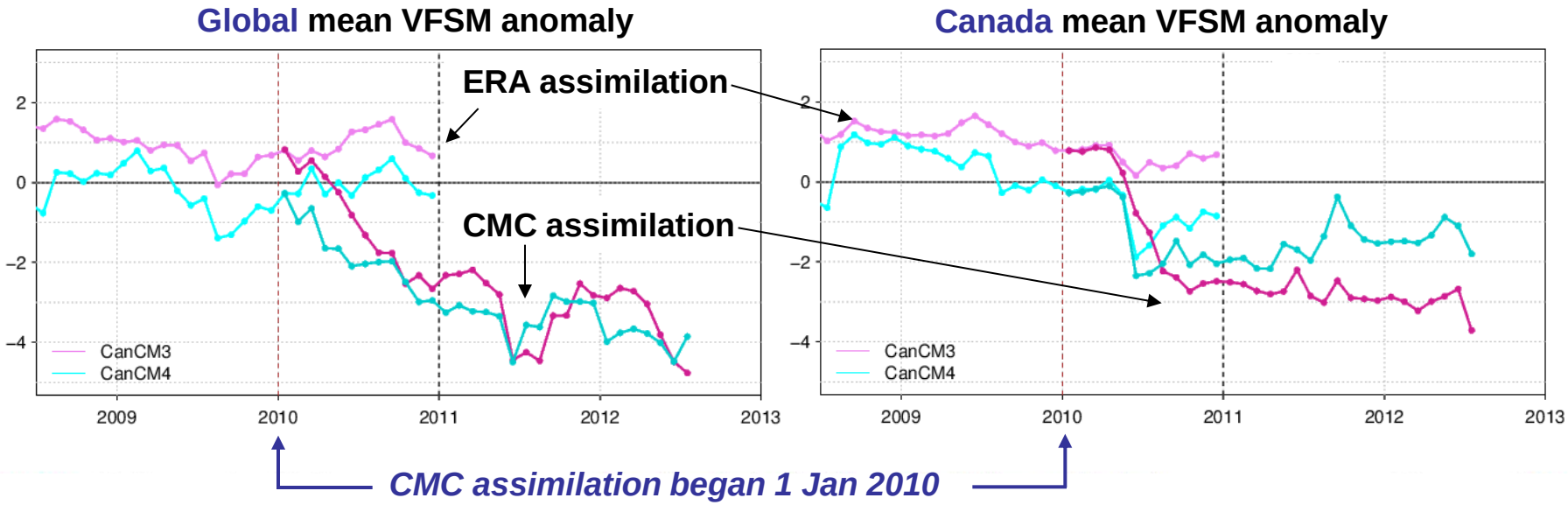
Data Sources: Hindcasts vs Operational

Field	Data Source during hindcast	Data Source during operations
3D atmospheric variables	ERA40; ERA interim	CMC
SST	monthly NCEP ERSST (1979-1981) weekly NCEP OISST (1981-present)	daily CMC
Sea ice concentration	monthly HadISST (1979-present)	daily CMC
3D ocean temperature	monthly NCEP GODAS ocean analysis	daily NCEP GODAS ocean analysis* *pending availability of CMC NEMOVAR analysis

Change in atmospheric data source: Effect on soil moisture

- Plots below compare soil moisture in first forecast month for ERA vs CMC-based initialization
- VFSM = volume fraction of soil moisture (%)
- Anomalies are relative to 1981-2010 hindcast climatology

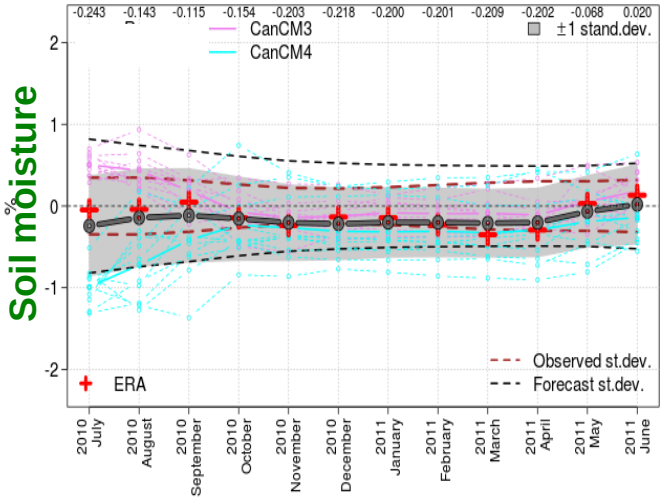
CanCM3
CanCM4



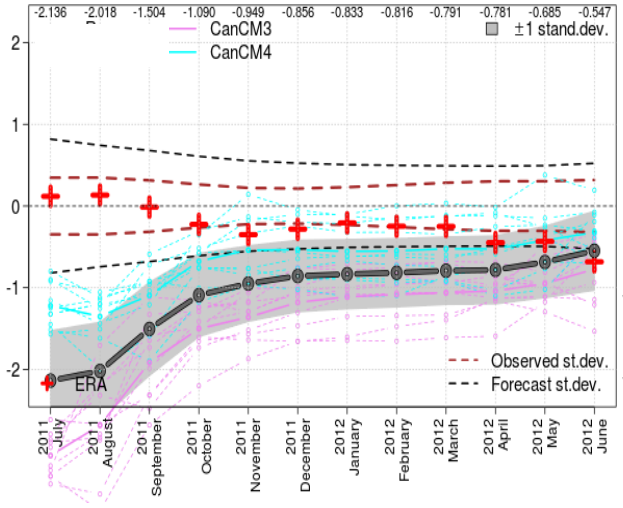
Canada mean soil moisture anomalies in July initialized forecasts

CanCM3 — CanCM4 — Grand ensemble mean + ERA interim verification

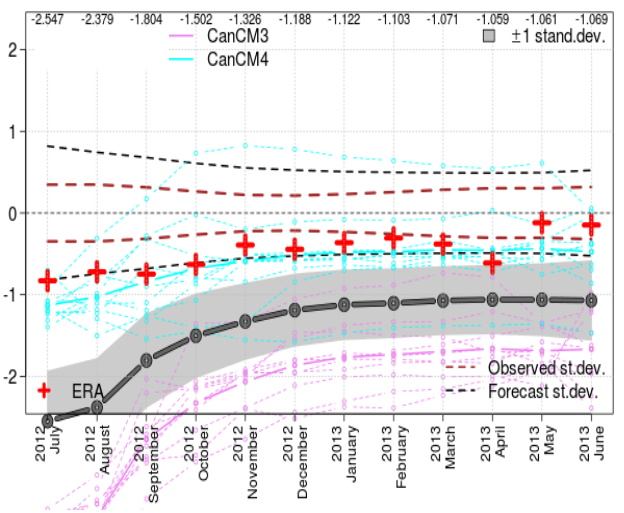
2010 (ERA)



2011 (CMC)



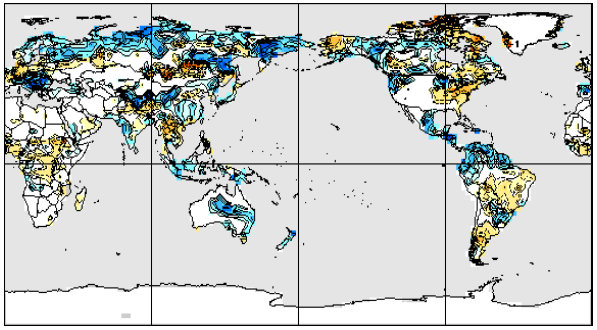
2012 (CMC)



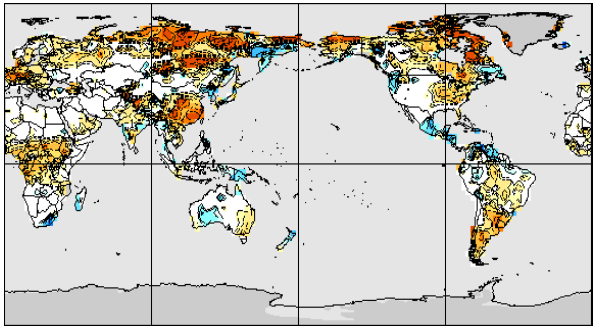
Forecast month

July lead 0 soil moisture anomalies

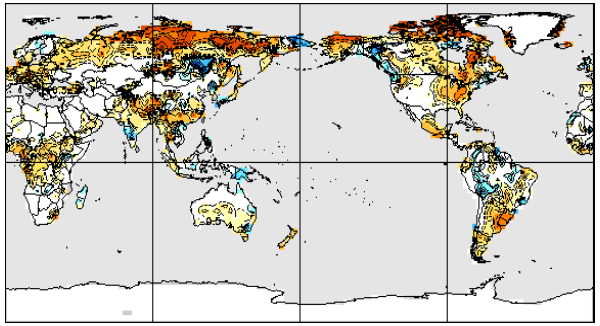
2010 (ERA)



2011 (CMC)



2012 (CMC)



DRY WET

Solution: Modify CMC-based assimilation runs using bias correction method of Kharin & Scinocca (*GRL* 2012)

1. Extend ERA-based assimilation runs to mid-2012

2. From these runs make 6-hourly soil moisture time series from 1 Jan 2010

3. Repeat CMC-based assimilation runs, assimilating soil moisture from ERA-based runs from step 2 using:

model soil moisture

assimilated ERA-based soil moisture

usual model equations $\frac{\partial X}{\partial t} = F(X)$ $- \frac{1}{\tau}(X - X_R)$ assimilation terms

4. Construct cyclostationary bias correcting forcing ("*G*") from soil moisture assimilation term:

$$G = -\frac{1}{\tau}\overline{(X - X_R)}^{AC}$$

mean annual cycle

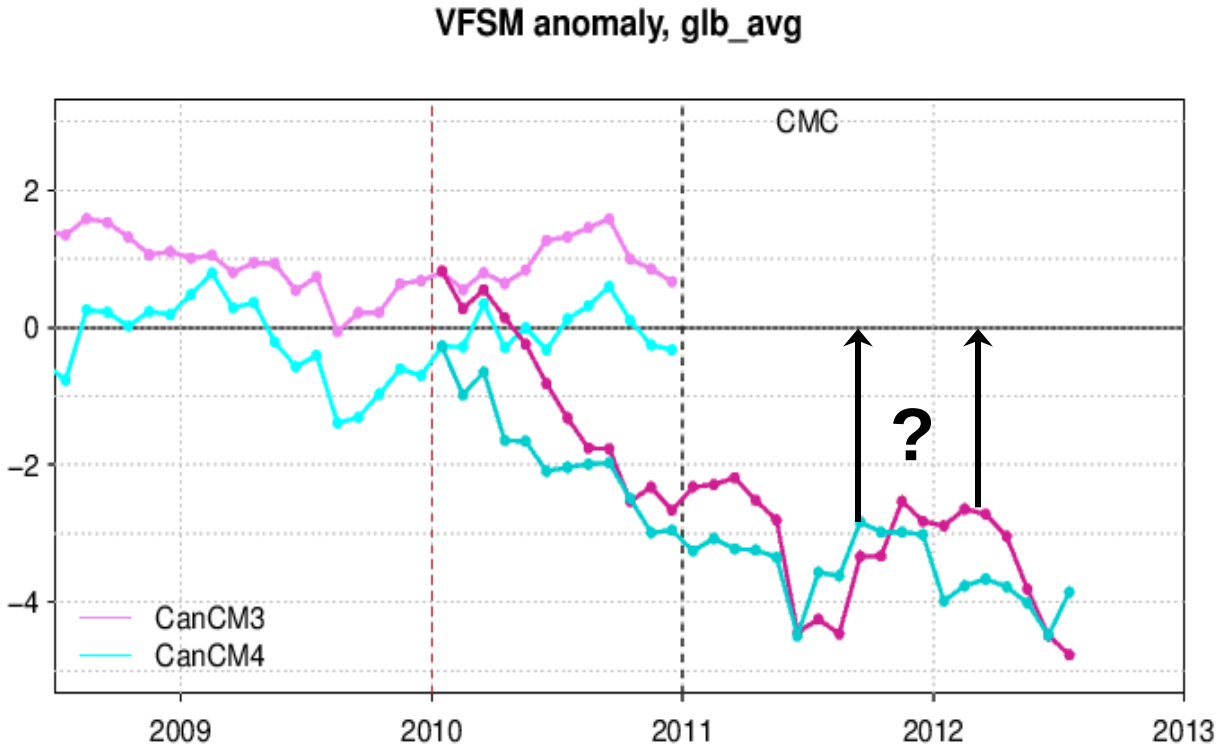
The bias correcting term "*G*" is not a relaxation term. For a given grid point, it only depends on the day of the year.

Solution: Modify CMC-based assimilation runs using bias correction method of Kharin & Scinocca (*GRL* 2012)

5. Repeat CMC-based runs again w/o soil moisture assimilation but with this bias correction

$$\frac{\partial X}{\partial t} = F(X) + \boxed{G}$$

6. Anticipated result: soil moisture drift corrected

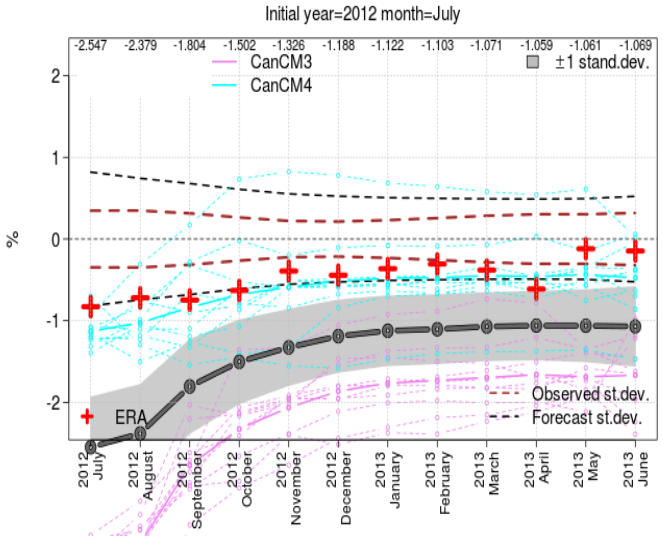


Result: Soil moisture restored to hindcast climatology in operational forecasts

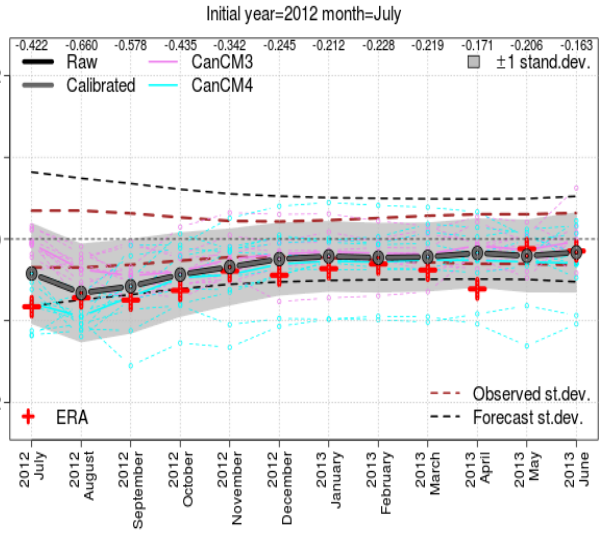
Canada mean soil moisture anomalies in July initialized forecasts

CanCM3 — CanCM4 — Grand ensemble mean — + ERA interim verification

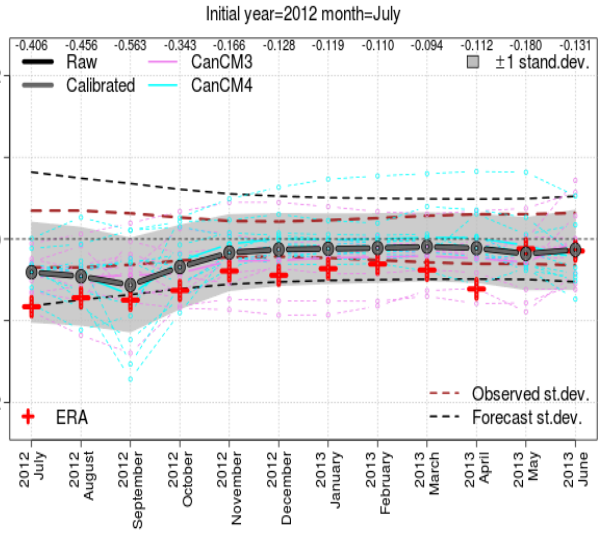
2012 (CMC)



2012 (ERA)



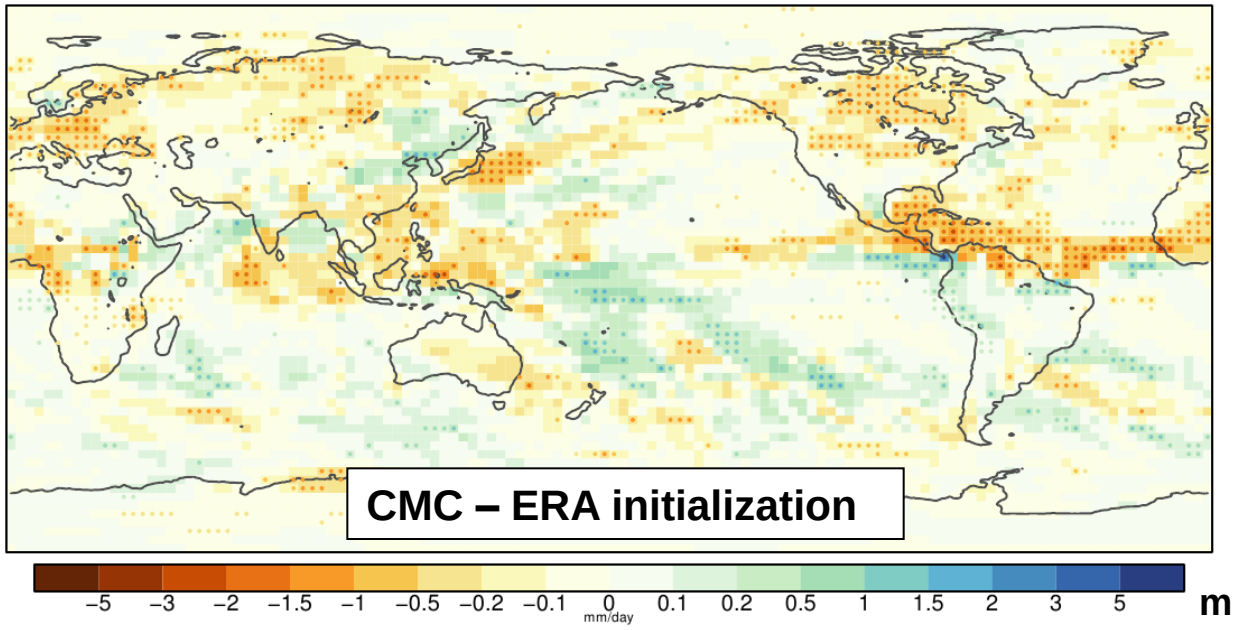
2012 (corrected CMC)



➡ ***Correction implemented operationally beginning with June 2013-initialized forecast***

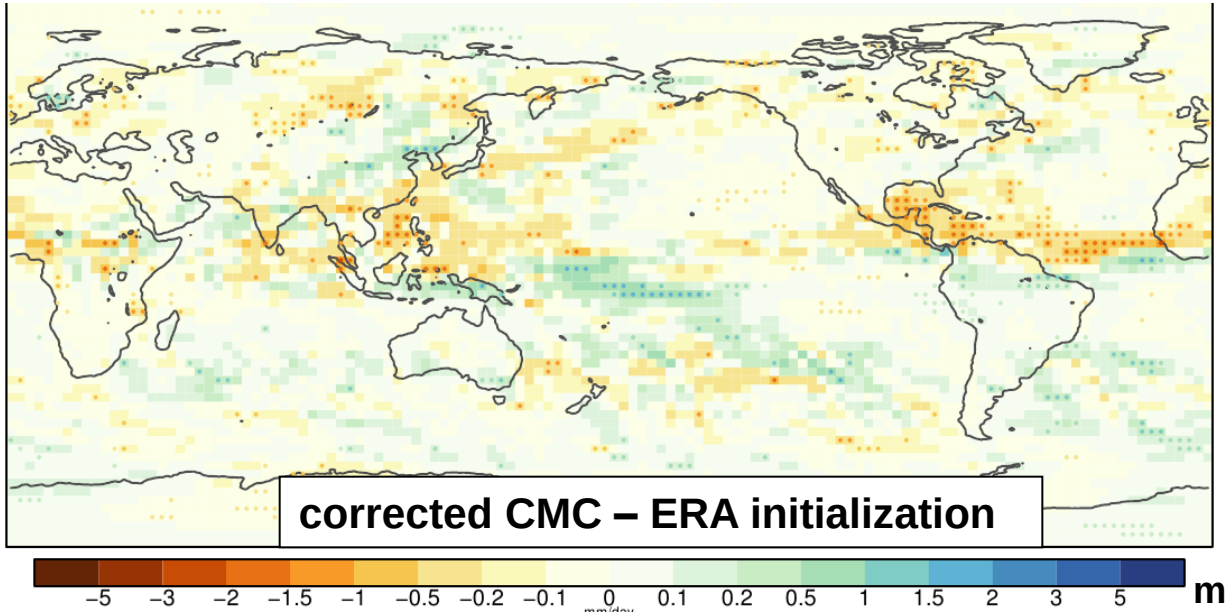
Effects of soil moisture biases on precipitation forecasts

Mean differences in JJA forecasts for 2010-12 (lead 0)



mm/day

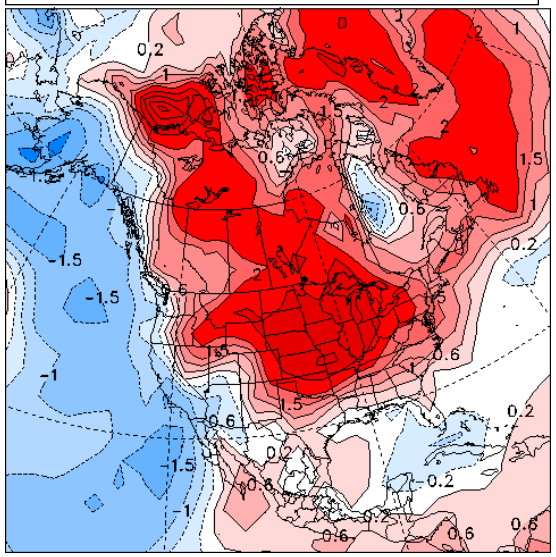
Dots indicate statistical significance according to t test



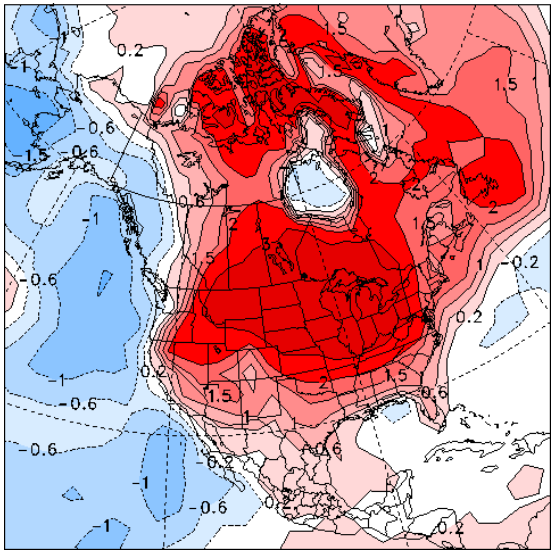
mm/day

July 2012 temperature anomaly forecast

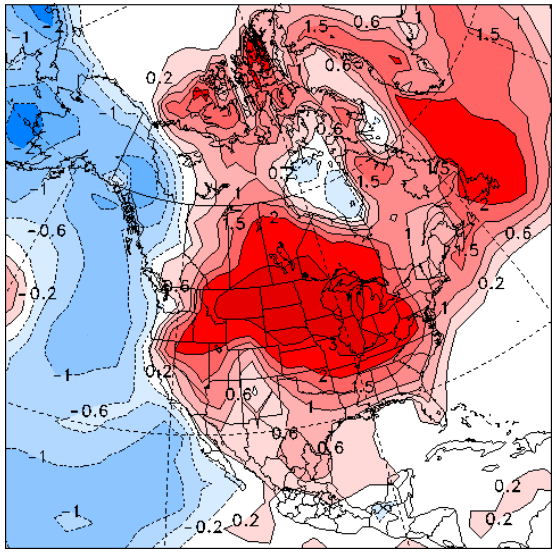
ERA Interim verification



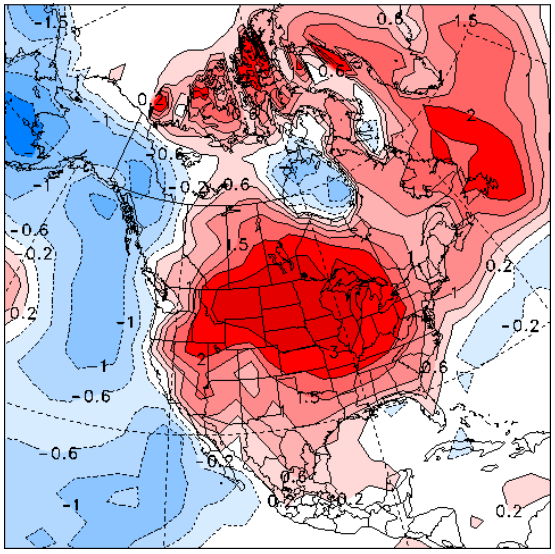
CMC initialization



ERA initialization



corrected CMC initialization



Summary

- Change from ERA reanalysis for atmospheric assimilation in hindcasts to CMC analysis in operational forecasts led to *accumulating soil moisture deficit*
- This has been fixed using the bias correction procedure of Kharin & Scinocca (*GRL* 2012)
- Soil moisture in hindcasts is OK
- Soil moisture in operational forecasts produced after June 2013 inclusive is OK
- Soil moisture in operational forecasts produced from Nov 2011 to May 2013 inclusive suffers from this bias

Thanks !